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# Causes, Effect and Abatement Measures of Flooding in River Ajilosun Drainage Basin in Ado-Ekiti, Nigeria

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**The paper examined causes, effect and abatement measures of flooding in River Ajilosun drainage basin in Ado-Ekiti, Nigeria. Data were collected on morphometric variables such as channel width and channel depth which were measured with ranging pole and tie rod. Channel efficiency was derived from a mathematical relationship between the channel capacity and the wetted perimeter of the channel. Data on slopes were obtained with Abney level. Data were also obtained on distance of buildings to river valley with a tape measure. 150 copies of questionnaire were also administered systematically to landlords of houses along River Ajilosun in order to obtain information on experience and effect of flooding in the basin. The study employed both descriptive and inferential statistics to analyze the data. The outcome of the descriptive analysis revealed illegal dumping of refuse in stream channel as the principal cause of flooding in River Ajilosun. Other causes of flooding are the heavy and frequent tropical rainfall in the area. The results of the quantitative analysis showed that the geomorphological variables accounted for about 80% of the total variation in spatial extent of flooding in the drainage basin. The analysis also revealed the number of channel obstructions (+29.6%) as the best predictor of flooding in the drainage basin. Other close predictors are channel slope (8.6%) and channel width (6.3%). Effects of flooding in the basin include erosion of foundation of houses, refuse sedimentation of streets and destruction of riparian vegetation among others. The paper recommends effective floodplain/slope management, provision of adequate waste disposal facilities and implementation of Town Planning Regulations as some of the measures that can be adopted to mitigate flooding in the drainage basin.**

**Keywords:** Flooding, River Ajilosun, Abatement and Drainage

## INTRODUCTION

Flooding is an exceptionally high level of water rising to submerge an area of land which is normally dry (Adebayo, 1987; Ayoade, 1988; Oriola, 2000; Adebayo and Jegede 2010; Arohunsoro, 2011). This definition applies generally to any type of flooding. However, flooding in river is a situation whereby water carried in a channel is in excess of the hydraulic capacity of the river such that it causes spilling of water on to the adjacent areas of the river. Flooding is a geophysical process which follows the occurrence of floods in any part of a geographical space.

The study of river flooding in cities is very important to continue sustainable growth and development of cities. Such a study is particularly important when flooding relates to the situation in a drainage basin. A drainage basin is an entire area of land where water and debris are channeled into and out of a trunk stream through a network of tributaries. Since cities occupy, inhabit and develop water sheds (drainage basins), modifications accompanying drainage basin terrains may predispose it to flooding hazards if appropriate management measures are not put in place (Arohunsoro, 2011). Proper management of floods in the water shed of cities is very crucial in the contemporary world because of the necessity of enshrining a disaster free urban environment.

River Ajilosun traverses the terrains of Ado-Ekiti, the capital of city of Ekiti State in Nigeria. The river has a drainage area which is constantly brought under the adverse effect of excessive storm flows particularly during the peak of rainy season. Several losses following ravaging floods have been incurred by occupants of the drainage basin including the losses running to several billions of Naira in Nigeria term, and also loss/wastage of 'human capital'. Annual flooding events in the river's drainage basin have generated constant embarrassment and cause serious concern for individuals, corporate bodies and government at local and state levels.

In the light of the above, the paper traces the causes of flooding discusses its effects and suggests measures for controlling the phenomenon of flooding in the drainage basin. These fundamental objectives are considered germane to the

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sustainable environmental development of the city. More so that the recent clamour across the globe is for the overall development of human environment, an effort in the direction of putting up control measures on flooding couldn't be an over estimated step in the right direction to the overall development of environmental and human resources within the drainage basin.

## OBJECTIVES OF THE PAPER

The specific objectives of the paper are to:

i. identify the factors causing flooding in River Ajilosun drainage basin
ii. examine the effects of flooding in River Ajilosun drainage basin
iii. suggests measures for abating flooding in the drainage basin.

## HISTORICAL EPISODES OF FLOODING IN ADO-EKITI

The establishment of Ado-Ekiti as the headquarters of Ekiti Division in 1953 marked the beginning of rapid urbanization and increased spatial expansion of the settlement. However, between 1976 and 1986 serious flooding had begun to take its toll in the town. The hazards caused by the flooding ranged from destruction of household properties in various parts of the town to sinking and collapse of the building (Table 1). Over the decade in reference losses incurred as a result of flooding in the town was estimated at about N2.5 million naira in the Nigeria context (Adebayo 1987; Ebisemiju, 1993a). According to Ebisemiju (1993a), about 95% of the losses were incurred by residents along River Ajilosun (Table 1).

Since the year 2002, flooding has become an annual experience in Ado-Ekiti, following the creation of Ekiti State in 1996, particularly along the watersheds of the rivers traversing the city terrains. But of particular significance is the notoriety of the flooding of River Ajilosun drainage basin. A commercial motorcycle operator was lost to the floods of Thursday, 21st September (Table 1).

Several houses were submerged at Olorunda/Olorunsogo Streets of the River Ofin drainage basin during the prolonged rains of October 2009. The floods of the year also led to the collapse of the popular Ajilosun bridge resulting in traffic diversion and delays. The flood water also swept away vegetable and maize farms in the downstream reaches of River Ajilosun. Many roads in the city were also rendered impassable because flood-erosion created deep – pot holes and craters on them.

On Sunday October 23rd, 2010, a six year old girl drowned in a ditch behind Mountain of Fire and Miracles Church of Adeparusi Off Opopogbooro during an early morning down pour which lasted for almost 4 hours (0630HRS – 1000 HRS GMT). The State Emergency Management Agency (SEMA) is institutionally concerned with coordinating of relief activities for the victims of natural disaster such as flooding. In 2005/2006, victims of flooding were given bags of rice and bundles of zinc roofing sheets.

Given the extent of damage caused by flooding in Ado-Ekiti, and particularly in River Ajilosun drainage basin, there is the danger of becoming myopic about the potentially hazardous situation of flooding in River Ajilosun drainage basin if sustainable control measures are not putting in place. At present, hazards are confined to built up areas which border the main stream channel and stream valley.

We must recollect that flooding in Ibadan started gradually on a mild note (Akintola, 1966), but today it has assumed catastrophic dimensions in the city (Obateru, 1978). Consequent upon the foregoing highlights, flooding in Ado-Ekiti requires proper attention. This is in a bid to forestall its incident from reaching a national disaster level like Ogunpa floods of 31st August, 1980 at Ibadan (Olaniran, 1983) and the widespread flooding in the city on Friday 26th August, 2011.

### Some Instances of River Flooding in Nigeria Cities

River flooding constitutes serious environmental problems in cities in Nigeria. Most major rivers are flooded annually particular during the peak of the rainy season when storms generate flows in excess of the river channel capacity. Notable river flooding in Nigerian urban centres include those of Asa in Ilorin city (Jimoh, 1997), Ala in Akure, Ondo State (Okoko and Olujimi, 2002), streams in Ado-Ekiti (Adebayo, 1987; Ebisemiju, 1993a) and River Ogunpa in Ibadan (Akintola, 1981). Other researches on flooding in Nigerian cities also include the works of Rasid (1982) in Benin City, Babatolu (2000) and Oriola (2000) in Ondo city in Ondo State.

Flooding of rivers is more regularly experienced in the Southern littoral region of the country because of the intensive equatorial rainfall and their proximity to the incursion of the sea waves and tides. In Northern dichotomy, flash flooding of rivers exhibits peculiarity due to the erratic nature of the rainfall regime. The onset of the rainy season is usually marked with torrential rain causing instantaneous/disastrous flooding. The South Western bloc of the country is exposed to more regular flooding of the major rivers and the water courses within the major cities and other human agglomerations.

The more regular humid nature of the region predisposes it towards more perennial flooding. No matter the perspective from which factors generating flooding in the country is viewed, the fact remains that flooding annually takes its toll in Nigeria and the current episode of climate change across the globe may likely push the country to a greater degree of vulnerability to the phenomenon.

## THE STUDY AREA

River Ajilosun drainage basin is located in Ado-Ekiti, the capital city of Ekiti State, within Latitudes $7^0 35^1$ and $7^0 38^1$ North of the Equator and Longitudes $5^0$ $10^1$ and $5^0$ $15^1$ East of the Greenwich Meridian (Fig.1). It has a drainage area of $18.125km^2$ and straddles the North West-South East axis of the city landscape. The drainage basin is a 4th order using Strahler's (1952) ordering method. The trunk flow, Ajilosun, has a main channel length of 6.20km. The basin has 22 short first order stream segments (Fig). However, almost all the streams have either been eutrophicated as a result of urbanization or concrete-lined to improve the drainage system of the city. Table 2 shows some morphometric parameters of River Ajilosun drainage basin.

The drainage basin like the entire Ado-Ekiti city falls within the tropical climate belt. The climate of the area is determined by the interaction between the dominant. Tropical maritime and Tropical continental air masses. Rainy season spans late March to November, although there may be false start of rains in February. Mean monthly rainfall totals is heaviest in June and September which coincides with the double maxima occurring after the passage of the overhead sun (Fig 2). Annual rainfall totals vary between 1200mm and 1400mm (Fig) Rainfall is characteristically highly intensive with 75% of the rainfall type exhibiting medium to high intensity (Adebayo, 1993). Relative humidity is never less than 80% in the rainy season while in the dry season it can be as low as 30%. Temperature distribution in the area follows closely the rainfall patterns, although temperature is generally high throughout the year with a mean monthly value of about $28^0$C, the annual range of temperature in the drainage basin can be as low as $3^0$C. Rainfall regime in July, September and October is very symbolic for flooding because of its effect on infiltration rate and runoff generation.

The drainage basin just like the entire city consists of an undulating relief. The highest point in the drainage basin is 540 metres; the regolith mantled Ayoba hill which stood at 1750ft above the pediments. The lowest point which is 390 metres occurs in the middle of River Ajilosun channel. Thus the relative of the drainage basin is 150 metres (Fig 3). Geologically, River Ajilosun drainage basin is predominantly underlain by the coarse-grained charnockite rock forming about 86 of the basin area. Other rock types in the drainage basin are the medium-grained biotite hornblende-granite, quartz and recent alluvial deposits of clay and mud in the river channels (Table 3).

Soils in the area closely related to the geological formations and the rock type. Soils are predominantly ferruginous, typical of basement complex rock areas of South Western Nigeria. Soils of thin and shallow depth are restricted to the slopes and scarps of mountains and hills. Heavy slope and red deep soils often containing high laterite content are found as detritus at the foot of slopes. The depth of soils in the area reflects the depth of chemical weathering which varies between 1 and 14 metres (Adeniyi, 1993).

The major land use types along the stream courses in the drainage basin consist of the residential (45.53%), commercial (0.63%), transportational (26.25%), educational (12.07%), recreational (0.60%), water resources (8.09), agriculture (1.45%) and open spaces (4.17%). Current rapid urbanization of Ado-Ekiti has generated an increase in the impervious areas in the city and in particular in the drainage basin through tarred roads, concrete pavements around homes and office complexes (public institutional edifices).

As at 2010, there were -km of tarred roads in the city. This is capable of modifying rainfall – runoff characteristics of the urban area. The various ongoing processes of urbanization may have also affected the vegetation of the environment. As of today, the primeval forests are restricted to the scarps of the inselbergs and the regolith-mantled Ayoba hill in the north-west segment of the drainage basin (Figure 4). Riparian bushes are also found along the streams and particularly along River Ajilosun banks.

However, dominant plant species are <u>*Panicummaxima*</u> (elephant grass), <u>*Sidaacuta*</u> (goat weed) and chromolaem, while the major tree types are <u>*TripochitonSceroxylon*</u> (Arere), *Terminaliasuperba* (Afara), <u>*AntiarisAfricana*</u> (Oriro) and *CeibaPentadra* (Egungun). The trees are found in their scattered nature doting the landscape in isolated stands.

**METHOD OF STUDY**

The data used in the paper were generated through direct field measurement of morphometric variables of River Ajilosun such as channel width, channel depth and hydraulic radius. Channel width was measured with the linen tape. The channel width was measured cross-sectionally at every 10 metres along the river's profile. Then the mean value of the various measurement was taken as in Figure 8. The measurement of channel depth was obtained with the use of a ranging pole and a piece of flat board 1.5 metres in length and graduated in the tenth of a metre. Channel depth measurements were taken along a transect by taking a number of measurements along each transect. The average value of the measurements were then taken. Measurements of geomorphological variables such as valley slopes, ground slope and channel slope were obtained with the aid of an Abney level; a slope measuring device. The distance of buildings to the river channel and extent of flooding along River Ajilosun valley were measured with the tape. Each measurement was taken at every 10 metres along the river channel. However, the hydraulic radius which defines the efficiency of River Ajilosun channel was derived from the mathematical relations of the mean channel area and the wetted perimeter of the channel thus:

$$Hr = A/Pw \quad \ldots\ldots\ldots\ldots \quad (1)$$

Where Hr is hydraulic efficiency;
A is channel area;
And Pw is wetted perimeter of the channel.

But Pw was derived as $2d+w$ ……………… (2)

Where W is channel width;
And d is channel depth;

Physical counting of the various types of channel obstruction was done by traversing the river from its source to where it ends in the town. Channel obstructions are defined in relation to the number of refuse dump sites, rock outcrops in channel and number of bridges and culverts across the river channel.

In addition to the direct field measurement, one hundred and fifty (150) copies of structured questionnaire were administered to landlords of houses along the river valley in order to assess their experience of flooding, and obtain their opinion about flooding hazards in the drainage basin. The questionnaire were systematically administered in every $5^{th}$ house along the river's channel by the author and the trained research assistants. The questionnaire administration was carried out between April and June, 2010.

The various data were analysed by computing the mean, range, standard deviation and also by computing their percentages. Pearson's correlation coefficient was computed between width of flooding and the geomorphological parametres in order to ascertain their level of relationship. The hypothesis raised was tested with the linear regression analysis and Analysis of Variance (ANOVA). The regression model is of the form:

$$Y = a + b_1x_1, b_2x_2, b_3x_3 \ldots\ldots b_nx_n \ldots\ldots\ldots \quad (3)$$

Where Y is mean width of flooding;
'a' is the intercept of the slope of the graph;
and $b_1 \ldots b_n$ are the regression coefficients.

Hypothesis was rejected where calculated 'F' value exceeds the critical (table) value. In addition to the statistical techniques, data were also illustrated by graphs and charts where appropriate.

**Table 1: Record of Flooding Events in Ado-Ekiti**

| S/N | Date | Location | Effect | Relief Measure(s) |
|---|---|---|---|---|
| 1. | 1976-1986 | River Ajilosun | Household properties damaged, building subsidence/collapse, losses estimated at ₦2.5 million | Nil |
| 2. | Thursday Sept. 21st, 2006 | River Ajilosun | 3 people drown including a commercial motorcycle (Okada) rider and 2 hawkers of petty wares | Nil |
| 3. | Sept. 2009 | Olorunsogo, off Opopogbooro – Adebayo Road | Houses submerge by flood and personal effects destroyed | Nil |
| 4. | Sept. 2007 | River Elemi | River Elemi bridge washed away, 3 university students died in automobile accident, caused by travelling on the badly eroded and dilapidated bridge on River Elemi | Nil |
| 5. | Sept. 2009 | Ajilosun | Popular Ajilosun bridge collapsed, caused traffic diversion and delays for several days | |
| 6. | Sunday, Oct. 24th, 2010 | Adeparusi Opopogbooro | A six (6) year old girl drowned in a ditch while going to church service in the morning. | State Government promised to construct the drainage channels in the area and rehabilitate the old ones |
| 7. | Oct. 27th, 2010 | Adebayo Street | Bookshop owned by a widow flooded; stationeries worth N1 million destroyed | |
| 8. | Sept 2nd, 2011 | Adebayo Street, Opopogbooro, Mercy land Moferere, Oke-ila, Olope | One small boy drowned in flood submerge open soakaway, several houses flooded, personal effects destroyed | Roofing sheets, cement mattresses |

**Source:** Adebayo (1987), Ebisemiju (1993), Ekiti SEMA, Fieldwork by the Authors, 2011.

**Table 2: Morphometric Parameters of River Ajilosun Drainage Basin.**

| Morphometric Parameters | Value |
|---|---|
| Area | 18.125km$^2$ |
| Perimeter | 16.05km |
| Basin length | 4.70km |
| Relief ratio | 0.72km |
| Elongation ratio | 0.91 |
| Circulatory ratio | 0.88 |
| Basin form | 0.82 |
| Total channel length | 40.11km |
| Main channel length | 6.20km |
| Number of 1st order channels | 22 |
| Number of 2nd order channel | 5 |
| Number of 3rd order channels | 2 |
| Number of 4th order channel | 1 |
| Drainage density | 1.90km/km$^2$ |
| Mean bifurcation ratio | 3.0 |

**Source:** Authors' calculations from the topographical map of the drainage basin.

**Table 3: Percentage of Rock Types in River Ajilosun Drainage Basin**

| Rock Type | Area of Basin Covered (Km$^2$) | % of Drainage Basin |
|---|---|---|
| Charnockite (coarse-grained) | 15.625 | 86.21 |
| Alluvial | 1.375 | 7.58 |
| Quartz | 0.750 | 4.14 |
| Medium-grained-biotite-hornblend-granite | 0.375 | 2.07 |
| Total | 18.125 | 100.00 |

**Source:** Authors' calculations from the geological map of Ado-Ekiti by Adeduro (1993).

**Table 4: Descriptive Analysis of Geomorphological Parameters of Flooding in River Ajilosun Drainage Basin**

| | Variable | Mean value | | Standard Deviation | Range | Std Error Mean |
|---|---|---|---|---|---|---|
| 1 | Width of flooding | Upper segment | 77.58 | 57.004 | 64.46-90.70 | 6.582 |
| | | Lower segment | 66.87 | 50.732 | 55.20-78.55 | 5.858 |
| 2 | Valley slope | Upper segment | 3.89 | 2.073 | 3.40-4.35 | 0.239 |
| | | Lower segment | 4.86 | 3.855 | 3.97-5.25 | 0.445 |
| 3 | Channel efficiency | Upper segment | 2.17 | 3.655 | 1.88-2.46 | 0.665 |
| | | Lower segment | 2.24 | 2.813 | 0.25-4.23 | 1.026 |
| 4 | Channel slope | Upper segment | $11.12^0$ | 4.651 | $7.77^0$-$14.47^0$ | 2.391 |
| | | Lower segment | $14.33^0$ | 6.135 | $9.26^0$-$19.21^0$ | 1.612 |
| 5 | Ground slope | Upper segment | $5.05^0$ | 2.235 | $0.05^0$-$11.0^0$ | 0.085 |
| | | Lower segment | $6.05^0$ | 2.512 | $0.05^0$-$12.0^0$ | 0.25 |
| 6 | Number of channel obstructions | Upper segment | 14 | | | |
| | | Lower segment | 10 | | | |

**Source:** Authors' calculation

**Table 6: Relative Contribution of Geomorphometric Parameters to the Prediction of Width of Flooding in River Ajilosun Drainage Basin**

| Model | Unstandardised Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | | |
| 1 (Constant) | 35.190 | 0.048 | | 13.456 | ***.023 |
| Mcd | -1E-014 | 0.050 | -.272 | -6.131 | .286 |
| Mcw | 6.3E-015 | 0.046 | .146 | 2.263 | ***.000 |
| Cc | 2.2E-016 | 0.053 | .122 | 0.021 | .130 |
| H radius Ce | -1E-015 | 0.313 | -. 084 | -2.237 | ***.003 |
| Mcs | 8.6E-016 | 0.736 | .055 | 1.532 | ***.008 |
| Mgs | 3.6E-015 | 0.812 | .341 | .745 | ***.002 |
| Vss | -5E-015 | 1.499 | -.135 | -.065 | .364 |
| Noc | 2.960 | 0.034 | -.661 | 8.631 | ***.000 |

**a. Dependent Variable: Y1 (mean values of flood belt width (FLOODING)**

***Source:*** *Computer Analysis*

## RESULTS AND DISCUSSION

### *Descriptive Statistics of the Measured Variables on Flooding*

The causes of flooding in River Ajilosun drainage basin are both descriptive and quantitative in nature. The descriptive causes are derived through the questionnaire administration by sampling the opinions of the respondents in respect of the causes and experience of flooding in the drainage basin.

### *Qualitative Causes of Flooding in River Ajilosun Drainage Basin*

The qualitative causes of flooding in River Ajilosun drainage basin as claimed by the residents of the drainage basin were heavy and frequent rainfall, dumping of refuse in the river channel, construction of buildings in the floodplains, absence of drainage channel and farming in the floodplains (Fig 5 & 5). Table 5 shows that 45.6% of the respondents said that indiscriminate dumping of refuse in the river/stream channels was responsible for the occurrence of flooding in Ajilosun drainage basin. This was in line with some earlier research reports that illegal dumping of refuse is a factor or urban flooding (Rasid, 1982; Olaniran, 1983; Adebayo, 1987; Ebisemiju, 1993; Adebayo and Jegede, 2010). However, greater proportion of the respondents in the downstream (non-concrete channelized) segment of the basin (27%) saw illegal dumping of refuse as the cause of flooding in the basin.

Again, 25.5% of the respondents surveyed claimed that heavy and frequent rains were the factor of flood generation in the basin. The result also agreed with some earlier studies that prolonged rainfall is a fundamental cause of flooding (olaniran, 1983; Adebayo, 1987; 1993; Ebisemiju 1993a; Babatolu, 1997; Oriola, 2000). This is because in the absence of rains, especially in the hinterlands of the tropical environment, there could be no overland flows generating floods not to talk of resulting to flooding of the terrains. When floods are initiated by heavy and prolonged rains, other factors come in to aid the incidence of flooding.

For example, where urbanization is intense as it is currently taking place in Ado-Ekiti, particularly on the floodplains, the hydrograph often shows rising limbs, and runoff is instantaneous. Figure 6 illustrates rainfall – runoff (hydrograph) of River Ureje at the Dam site. The hydrograph is characteristically associated with a gradually growing urban centre as observed in Ado-Ekiti.

Moreover, 6.7% of the respondents recognised construction of buildings in the floodplains of River Ajilosun a factor of flooding in the drainage basin. For instance, the mean distance of buildings to the banks of River Ajilosun was about 21±28.27 metres in the upper segment of the river valley while it was about 27±23.32 metres in the lower segment. But the mean distance of floodable terrain (land) in the upper River Ajilosun valley was 77.58±57.00 metres while the mean distance of the floodable land in the lower River Ajilosun was 66.87±50.73 metres.

The implication of this is that the building codes in respect of setback of houses to river valley were violated. In urban centres, laws are expected to effectively guide the urban land use practices and location of buildings. For example, Town Planning legislations require a setback to streams for any structure to be at least 20 metres in the low-density residential areas; and a minimum of 30 metres in the high-density areas (Oriola, 2000, p.107).

This law is flouted in Ajilosun drainage basin by construction buildings in the floodplains of the basin. The implication of erecting buildings in the floodplains of River Ajilosun is that, the sinking of heavy foundations on the floodplains, especially flood walls, which are necessary for construction in the floodplains, will impede interflow in the floodwalls soils. This will keep the soil under semi-permanent saturation. This condition will result to immense to change in the hydrograph characteristics of the river valley (Akintola, 1981, p.153).

Furthermore, a low proportion of the respondents (1.35%) posited that, farming in the floodplains was also responsible for flooding of the drainage basin. Farming activities break soil structure and its cohesiveness through the clearing of vegetation. This results to the loss of permanent vegetal cover and its role in providing a binding effect on the channel soils. Through this, the absorbent role of vegetation on storm flow is averted thereby causing puddles (stagnant pools of flood water) in the surroundings of the river valley. So far, we have seen that urban development factors and climatic peculiarities are the cogent causes of flooding in the Ajilosun drainage basin.

***Quantitative Causes of Flooding in River Ajilosun Drainage Basin***

The result of the statistical analysis of the geomorphological parameters of the River Ajilosun showed that the significant quantitative causes of flooding in the river are channel width, hydraulic radius, channel slope, ground slope and number of channel obstruction. The result of analysis in Table 6 shows that the variable contributed variedly to the incidence of flooding in the drainage basin.

The relative contribution analysis of the parameters revealed that the number of channel obstruction, mean channel slope and the mean ground slope make the most significant contribution to flooding in the drainage basin. The linear regression equation linking the width of flooding with the geomorphological variable of River Ajilosun is expressed by:

$$Y = 35.190 - 1(Mcw) + 6.3(Mcw) + 2.2(Cc) - 1(Ce) + 8.6(Mcs) + 3.6(Mgs) - 5.0(Vss) + 2.960(Noc) \text{-----------} (3)$$

$$R^2 = 0.801$$

Where, Mcd is Mean channel depth;
Ce is Channel efficiency
Mcw is Mean channel width;
Mcs is Mean Channel Slope;
Cc is Mean channel capacity;
Mgs = Mean Ground Slope;
Vss is Valley Side Sloe;
And, Noc = Number of Channel Obstructions.

The equation '3' shows that the mean channel width, the channel capacity, mean channel slope, mean ground slope and the number of channel obstructions make positive contributions to flooding in River Ajilosun drainage basin. Variables making negative contributions to flooding are mean channel depth, channel efficiency and valley side slope. In the overall the independent variables gave about 80.0% explanation of the variables in the extent of flooding in River Ajilosun (Table 7).

The F value (1125.15) of the Null hypothesis of no significant contribution of the geomorphological variables to flooding in the basin was rejected at 0.05 level of significance (Table 7). The implication of this is that the geomorphological variables make a significant contribution to flooding in River Ajilosun drainage basin. The channel depth with negative regression coefficient b(-1E-014) indicates a decrease in spatial extent of flooding with increasing channel depth. The implication of this is that, the floodable area of River Ajilosun valley may reduce with increasing vertical dissection of the river channels in the basin, if all other physical factors to maintain this are held constant.

Channel width with positive coefficient $b^2$ = +6.3E-015 indicates that increase in channel width may lead to increase in the spatial extent of flooding in River Ajilosun drainage basin. This is because as channel width increases more cross-sectional area of the channel comes under inundation. Channel width increase also occurs at the expense of the channel vertical dissection.

The positive coefficient of the channel capacity ($b_3$= +2.2E-016) is an indication of the positive contribution of the channel area to the extent of floodable area. The meaning of this is that as the cross-sectional area of the channel increases, the width or extent of floodable area will follow the same trend. The negative regression coefficient of the channel efficiency ($b_4$=-1E-015) means that as hydraulic efficiency of the channel increases, spatial extent of inundated area in River Ajilosun drainage basin may be expected to increase.

Different channel obstructions in the drainage basin include refuse of all sorts, channel rock outcrops, bridges/culverts, twigs or logs of wood. These materials disturb free flow of storm runoff and reduce the efficiency in evacuating floods. Channels slope with a positive coefficient ($b_5$=+8.6E-016) posits that channel slope made a positive contribution to the width of flooding. This implies increasing spatial extent of flooding with increasing channel slope. This may mean that increase in the gradient values of the channel will promote rapid water and debris runoff and the eventual evacuation of the channel storm flow.

Since the ground slope has a positive coefficient (b=+3.6E-015), then it implies that as ground slope increases, one expects the width of flooding to increase. One can then say that ground slope contributes to flooding in River Ajilosun drainage basin. Sloppy terrains will promote quick transportation of floodwater via the ground surface. The rapid evacuation of overland flow may not allow sufficient time for its infiltration. This process leads to instant peaking of the flood hydrograph of the drainage basin.

The near oval shape of the River Ajilosun drainage basin as indicated by the bifurcation ( $R_b$) ratio of 0.80 imply inclined terrains; and with the basin is high number of first and second order segments, flood obstruction may hamper smooth transportation of floods by the channel network. This will consequently bring spillage and lateral migration of the floods to adjacent areas of the river valley.

It is evidently revealed in the regression equation that the number of channel obstructions was the predictor of flooding in the Ajilosun drainage basin, with a better weight of 29.0%, exercising a high influence on flooding in the basin.

**Table 7: Model Summary of the Regression of Channel Flooding and Geomorphological parameters of River Ajilosun Drainage Basin**

| Model | Sum of Square | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| 1 Regression | 208467.94 | 8 | 69489.31 | 1125.15 | .0002 |
| Residual | 51382.26 | 141 | 61.76 | | |
| Total | 257850.20 | 149 | | | |
| **Model** | **R** | **R Square** | **Adjusted R Square** | **Std. Error of the Estimate** | |
| 1 | .896[a] | .803 | 801 | 7.878 | |

a. Predictors: (Constant), Noc, Vss, Mcd, Mgs, H radius Ce, Mcs, Cc, Mcw
b. Dependent Variable: Y1 (mean values of floodbelt width (FLOODING)
*Source: Computer Analysis*

**Table 8: Length of Floods in River Ajilosun Drainage Basin**

| Segment of the river | | flood length (from the valley to the building) | | | | Total |
|---|---|---|---|---|---|---|
| | | less than 50 minutes | 50 – 100 metres | 101 – 200 metres | More than 200 metres | |
| Upstream | count | 34 | 17 | 9 | 5 | 65 |
| | % of Total | 24.1% | 12.1% | 6.4% | 3.5% | 46.1% |
| Downstream | count | 34 | 20 | 20 | 2 | 76 |
| | % of Total | 24.1% | 14.2% | 14.2% | 1.4% | 53.9% |
| Total | count | 68 | 37 | 29 | 7 | 141 |
| | % of Total | 48.2% | 26.2% | 20.6% | 5.0% | 100.0% |

***Source:*** *Fieldwork by the Authors.*

**Table 9: Effect of River Ajilosun on the Foundation of Buildings in the Drainage Basin**

| Segment of the River | | River Ajilosun has effect on the exposure of your building foundation | | Total |
|---|---|---|---|---|
| | | Yes | No | |
| Upstream | Count | 46 | 21 | 67 |
| | % of Total | 31.7% | 14.5% | 46.2% |
| Downstream | Count | 60 | 18 | 78 |
| | % of Total | 41.4% | 12.4% | 53.8% |
| Total | Count | 106 | 39 | 145 |
| | % of Total | 73.1% | 26.9% | 100.0% |

***Source:*** *Fieldwork by the Authors.*

**Table 10: Height of Flood on Building Walls in River Ajilosun Drainage Basin**

| Segment of the river | | Flood depth (height of the flood on the building wall) | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | less than 0.5 meters | 0.5 – 0.8 metres | 0.8 – 1.0 metres | 1 – 1.5 meters | more than 1.5 metres | |
| Upstream | count | 24 | 27 | 5 | 4 | 5 | 65 |
| | % of Total | 17.1% | 19.3% | 3.6% | 2.9% | 3.6% | 46.4% |
| Downstream | count | 16 | 38 | 9 | 10 | 2 | 75 |
| | % of Total | 11.4% | 27.1% | 6.4% | 7.1% | 1.4% | 53.6% |
| Total | count | 40 | 65 | 14 | 14 | 7 | 140 |
| | % of Total | 28.6% | 46.4% | 10.0% | 10.0% | 5.0% | 100.0% |

***Source:*** *Fieldwork by the Authors.*

**Table 11: Types of Properties Affected by Flooding in River Ajilosun Drainage Basin**

| Segment of the river | | if yes, what types of property did you loose | | | | | Total |
|---|---|---|---|---|---|---|---|
| | | Money | household materials | lives | building collapse | other valuable (specify) | |
| Upstream | Count | 1 | 33 | 2 | 12 | 3 | 51 |
| | % of Total | 1.0% | 31.7% | 1.9% | 11.5% | 2.9% | 49.0% |
| Downstream | Count | 4 | 35 | 4 | 6 | 4 | 53 |
| | % of Total | 3.8% | 33.7% | 3.8% | 5.8% | 3.8% | 51.0% |
| Total | Count | 5 | 68 | 6 | 18 | 7 | 104 |
| | % of Total | 4.8% | 65.4% | 5.8% | 17.3% | 6.7% | 100.0% |

***Source:*** *Fieldwork by the Authors.*

**Table 12: Capacity Analysis of Some Storm Drains in River Ajilosun Drainage Basin**

| Location | Road width (m) | Width of drain (m) | Depth of drain (m) | Area of drainage ($m^2$) | Thickness of debris in- fill | Percentage effectiveness of drainage |
|---|---|---|---|---|---|---|
| Ajilosun old Garage road (Rd) | 9.20 | 0.80 | 0.80 | 0.64 | 0.70 | 12.50 |
| Old Garage OkeyinmiOjumose road (Rd) | 7.36 | 0.70 | 0.90 | 0.63 | 0.85 | 5.60 |
| Post office – Atikankan road (Ld) | 9.00 | 0.70 | 0.90 | 0.63 | 0.52 | 42.2 |
| Mathew junction – Irona road (Ld) | 13.00 | 0.60 | 0.60 | 0.36 | 0.45 | 25.00 |
| Mathew road (Rd) | 14.30 | 0.70 | 0.50 | 0.35 | 0.40 | 20.00 |
| = ∑x/5 | 10.57 | 0.70 | 0.74 | 0.52 | 0.58 | 21.06 |

***Source:*** *Fieldwork by the Authors.*
**Key:** Rd (Right drain); Ld (Left drain)

**Table 13: Compliance with the Local Building Plans Regulations in River Ajilosun Drainage Basin**

| Variable | | | Is there a building approval by a Local Planning Authority before the construction | | Total |
|---|---|---|---|---|---|
| | | | Yes | No | |
| Segment of the river | Upstream | Count<br>% of Total | 38<br>25.7% | 29<br>19.6% | 67<br>45.3% |
| | Downstream | Count<br>% of the total | 46<br>31.1% | 35<br>23.6% | 81<br>54.7% |
| Total | | Count<br>% of total | 84<br>56.8% | 64<br>43.2% | 148<br>100.0% |

***Source:*** *Fieldwork by the Authors.*

**Table 14: Methods of Waste Disposal Adopted by the Respondents in River Ajilosun Drainage Basin**

| Segment of the river | | methods of waste disposal | | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | | use of dustbin | indiscriminate dumping/open space | designated dumping site | communal sanitary land | along drainage channel | inside Ajilosun river | |
| Upstream | Count<br>% of Total | 24<br>16.2% | 4<br>2.7% | 15<br>10.1% | 6<br>4.1% | 14<br>9.5% | 5<br>3.4% | 68<br>45.9% |
| Downstream | Count<br>% of Total | 24<br>16.2% | 5<br>3.4% | 20<br>13.5% | 9<br>6.1% | 13<br>8.8% | 9<br>6.1% | 80<br>54.1% |
| Total | Count<br>% of Total | 48<br>32.4% | 9<br>6.1% | 35<br>23.6% | 15<br>10.1% | 27<br>18.2% | 14<br>9.5% | 148<br>100.0% |

***Source:*** *Computer Analysis*

This was followed by channel slope with 8.6%; channel width with 6.3%; valley slope, -5.0%; ground slope 3.6%; channel capacity, 2.2%; channel efficiency and channel depth, -1.0% each. Based on the findings therefore, it is obvious that the number of channel obstructions and channel slopes were the strongest factors in the incidence of flooding I River Ajilosun drainage basin.

### *Effect of Flooding in River Ajilosun Drainage Basin*

Flooding generates a number of effects in River Ajilosun drainage basin. In the first instance, flooding causes erosion of foundation of buildings in the Ajilosun drainage basin. Thereby exposing such buildings to the danger of dilapidation and collapse. This can bring about degradation of the structural quality of residential buildings in the environment. In the course of the study it was discovered that 48.2% of flood events in River Ajilosun drainage basin travelled up to 50 metres from the channel bank to the residential areas (Table 8) whereas the mean distance of buildings to the River Ajilosun bank was 20.53 metres in the upper reaches and 26.50 metres in the lower reaches of the river. This implies that proximity of the location of many houses to the river bank were exposed them to the cracking and peeling of their wall plasters and risk exposure of their foundation. For instance, during the questionnaire survey, 73.1% of the respondents affirmed that River Ajilosun excavates the foundation of their houses (Table 9).

Houses located in the floodplains of alluvial clastic sediments laid by flooding are gradually and imperceptibly affected by sinking into the marshy terrains. Also, in the upstream reaches of the drainage basin, between 17.1% and 19.3% of the cases of flooding experienced usually reached heights ranging from 0.5 to 0.8 metres on the walls of houses which is a serious threat to the sustainable existence of such houses (Table 10). In addition to the foregoing of River Ajilosun drainage basin has been associated with loss of valuable properties and even lives.

This is often brought about by excessively accumulated overland flow during stormy weather or peak weather flow. The questionnaire survey conducted in the drainage basin revealed that 65.4% of the effect of flooding involved loss of household and other properties while 5.8% of such effects involve loss of lives. (Table 11).

Ecologically related impacts of flooding in the Ajilosun drainage basin also include wanton destruction of valuable riparian vegetation. Such vegetation provides herbs, food and spawning space for aquatic organism, the obliteration of which can occasion ecological disruption in the environment. Similarly, flooding or River Ajilosun basin may cause the fragmentation of riparian tree canopy, the implication of which may reflect in the loss of habit structure of the aquatic ecosystem. Some herbs which have medicinal values may be disappearing from the aquatic ecosystem due to their repeated submergence by sediment deposition. Such situation was observed in the lower reaches of the river where there is relatively wider floodplain harbouring larger deposition of alluvial sediment.

Stream widening and mal-adjustment of the streams' channels' equilibria are some geomorphological hazards occasioned by the flooding of the drainage basin. The effects of these processes were conspicuously noticed in the lower alluvial channelized reaches of River Ajilosun. The mean channel width in the lower reaches was 8.37±2.26metres compared to an average of 3.39±1.92metres in the upper concrete-channelized segment. The difference is due to the increased channel flow which occasionally shifted channel geometry, particularly, during the peak stream flow. The resultant effect of this process may generate decreased channel stability in the drainage basin.

Flooding also causes refuse sedimentation of streets thereby generating pollution and unsightly scenes especially at road junction and beside storm drains. There are two consequences of illegal refuse disposal in water courses in the drainage basin. One, refuse chokes up channel and reduces the capacity of the channel to transport flood water. This leads to spillage of sediment of refuse on the adjacent areas of the channel. Situations like these are often experienced along the longitudinal profile of the River Ajilosun (plate 1, 2, & 3). Two, refuse choking up the stream channels also brought about spillage and deposits of alluvial sediments on the streets. This often results from the sub optimal efficiency of the storm drains which was as low as 21.1% in the lined drains of the major roads in the drainage basin (Table 12 )

Besides the foregoing, flooding also causes the sinking/subsidence of houses in River Ajilosun drainage basin. Subsidence is common with house at OdoAremu, OkeOri Omi, Orojuda, Atikankan and OdoOtu in the upper reaches of the drainage basin (Fig). the affected building in these areas are located in the flood plains where 'setting soils' (non cohesive alluvial deposit) form poor quality substrate for holding the weight or structure put on them on them. Plates 1 and 2 illustrate houses affected by subsidence and collapse respectively at Atikankan. The buildings reflect indirect impact of flooding on such houses. Plate 3 also shows a house at OdoAremu which are sunk to the window level. This particular house was once rented by the parents of the author in 1973. But today, it is abandoned, taken over by and serves as illegal communal dump site.

Apart from the effect of flooding on houses, capital infrastructure such as roads, electric poles and bridges/culvert were also vulnerable to the hazards of accumulated flows during storms. The popular Ajilosun Bridge along the Ado-Akure road collapsed during the September floods of 2009. The effect of the bridge collapse reflected in traffic delays and diversions causing hitch to government and private business transactions in the city. Besides the delay, sediments were laid along road sides creating temporary impasse to both human and vehicular traffic. From the foregoing discussion the effects of flooding in River Ajilosun basin can be summarized into erosion of houses, loss of household properties and at times lives. Other effects also include stream channel degradation, sinking/subsidence of buildings sedimentation of the streets and damage of physical infrastructure and obstruction in circulation within the drainage basin.

### *Measures for Abatement of Flooding In River Ajilosun Drainage Basin*

Abating the various effects of flooding in River Ajilosun drainage basin rests mainly on the effective organization and reorganization of the spatial fabric of basin space. In the first place house construction must be properly supervised and monitored. Most of the houses in the basin were illegally located in spate of the fact that 56.8% of the respondents claimed to have the approval of the Town Planning Authority before they were constructed (Table 13 ).

Construction by the Town Planning Authority would have prevented such illegal and inappropriate siting of houses to the river channel that is 3 dimetresunderstorm, should be enforced on every house owners. Again, provision of adequate waste disposal facilities are needed in order to guide and check indiscriminate disposal of refuse in to water courses and the roadside concrete lined storm drains. The respondents seize the opportunity of the proximity to the river channel and use it for refuse disposal; 9.5% of them claimed to have been using River Ajilosun Channel for disposing their waste (Table 14).

Therefore, to discourage this habit waste disposal facilities should be provided in adequate quantity along River Ajilosun and in other areas where houses are close to the water courses. Landlords of houses near the water courses should be saddled with the responsibility of acting as 'watch dogs' to arrest illegal refuse dumpers who convert the channels to dump sites.

In addition, there is the need to allow river/stream channels to follow their natural geometry when concrete channelization of such water bodies is to be carried out. Straightening of river/stream channel increases the speed of flood flow. But when channelization follows the natural bends of rivers, speed of water flow is reduced and less erosion is performed. Even in place of concrete lining of channels, urban agriculture and riparian vegetation should be allowed to flourish at the banks and valleys of River Ajilosun. Such areas could be also be developed into 'green belts' which will act as 'carbon sinks' and as well supply oxygen need of the city dwellers.

Again, regular cleaning of storm drains should be undertaken in order to desist and rid them of refuse that may block the free flow of storm runoff. Most of the existing lined drainages are grossly insufficient in their capacity to accommodate and transport excess runoff during and after rains. Since population is recently growing at a rapid rate, it requires that the capacity of the storm drains increase in tandem with the expanding impervious area of the drainage basin.

Also, effective management of slopes in the drainage basin is needed. Particularly the slopes of Ayoba hill must be properly protected against further urbanization otherwise shrubs and grasses must be planted to ground the residential buildings to prevent runoff and slope wash from the hill. Construction of the building on slopes on steep gradient should be discouraged by the town planning authority in order to ensure adequate safety factors around homes and prevent flashy floods and the base of such slopes.

Similarly, underground storm drains/sewers should be constructed at the point of intersection of the drains. It may also be necessary to construct sediment intake at road junctions at Atikankan, Ijigbo, Isato, Okebola-Mathew and OdoAremu roads.

## RECOMMENDATIONS AND CONCLUSIONS

Underlying every environmental problem, particularly flooding is the behavioural inclination of human being. Effective monitoring of human behavior in River Ajilosun drainage basin would have put a check on most of the problems of flooding. Therefore, regular environmental education and enlightenment campaigns will go a long way to ameliorating the dastard consequences of flooding in the drainage basin. The collaborative effort of individual, town development authorities and the state/local governments are indispensable for the effects of flooding in the drainage basin.

Since the city of Ado-Ekiti will continue to grow, and urbanization of the city is desired, definitely the extent of imperviousness of the city surface will grow. Consequently, the resultant increasing tendency of the Ado-Ekiti landscape, and effective management of the terrains and space of the River Ajilosun drainage basin, are germane to any of the measures suggested in this paper combat flooding in the drainage basin.

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